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Federal Communications Commission
Office of the Secretary

Frequency Agile Spectrum Access Technologies

Presentation to
FCC Workshop on Cognitive Radios
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List A B C D E



Agenda

- Requirements
- Spectrum occupancy characteristics
 - Significant amount of “low hanging fruit”
- Spectrum access methods
 - Listen-Before Talk
 - “TDMA” spectrum
 - Broadcast spectrum
 - Probe
 - Geo-location/database



Frequency Agile Radio Requirements

- Create insignificant interference
 - Secondary operation with minimal requirement for coordination with primary system licensees
 - Unlicensed with equipment certifications on a system basis to assure avoidance of interference
- Operate in multiple bands
 - Assured capacity
- Offer cost/capacity/link range/deployment benefits
 - Access more (5 X?) spectrum than any current system
 - Operate in VHF/UHF TV band
 - Rapid spectrum agreements for itinerate use



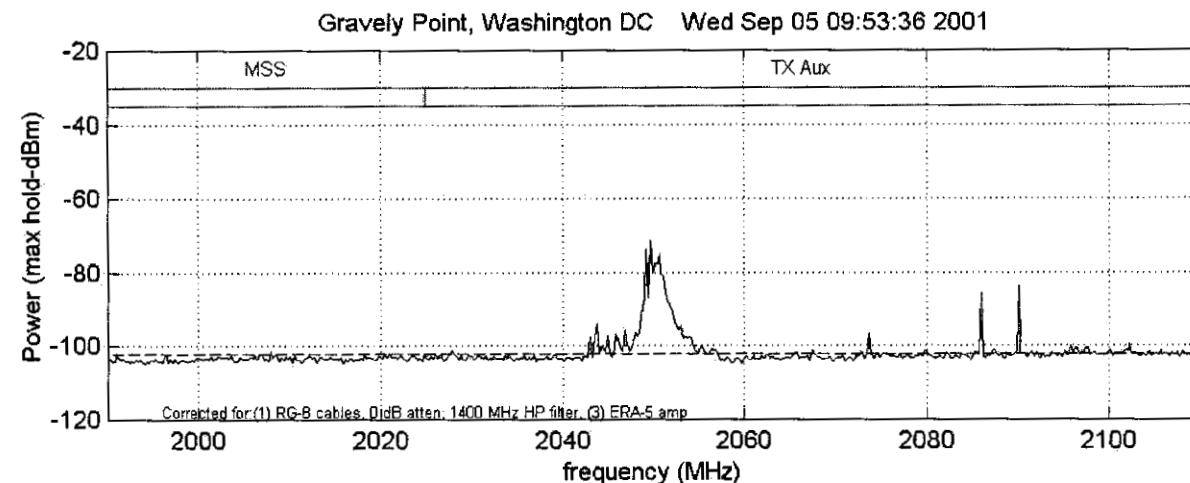
Spectrum Occupancy Is Low

- “In many bands, spectrum access is a more significant problem than physical scarcity of spectrum, in large part due to legacy command-and-control regulation that limits the ability of potential spectrum users to obtain such access.”¹
- Shared Spectrum’s measurements indicate
 - Many bands have no detectable occupancy
 - Some bands have low occupancy
 - Some bands have high occupancy

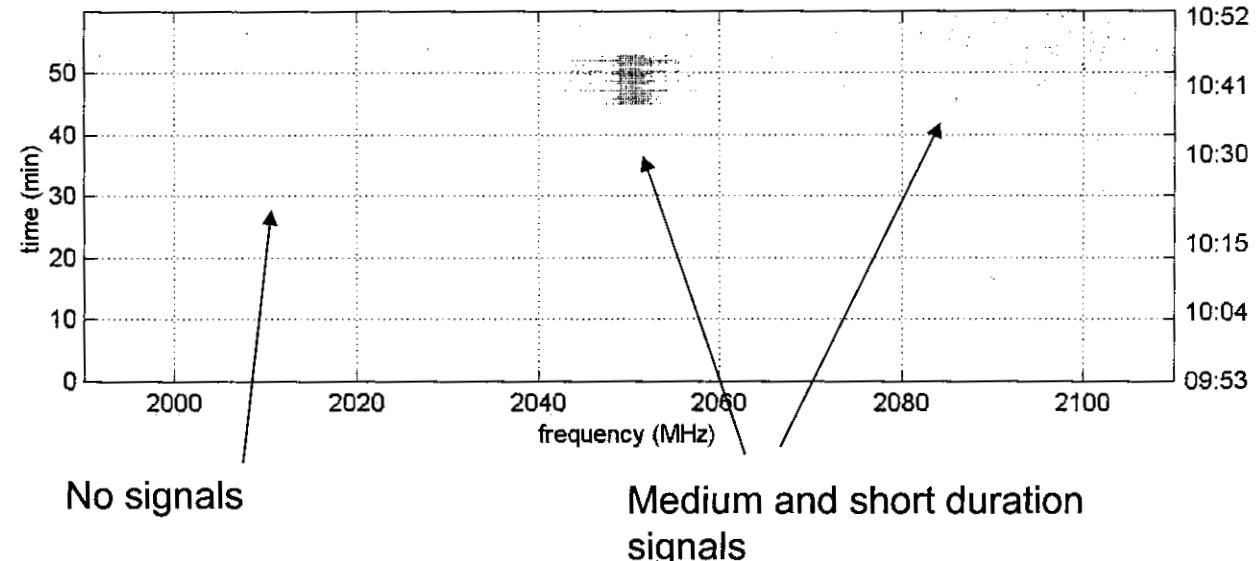
Note 1: FCC Spectrum Policy Task Force Report, page 3



Typical Spectrum Occupancy Measurement



FCC should conduct and publish spectrum occupancy measurements to identify low occupancy bands





Initially Harvest the Low Hanging Fruit

- Measurements show a large quantity of long duration, large area spectrum holes
- “Simple” spectrum access methods are sufficient
 - Minimal coordination between transceivers
 - Moderate computational costs
- Later evolve algorithms to handle more complex situations
 - Short duration, small spectrum holes
 - Optimize frequency assignments for increased capacity



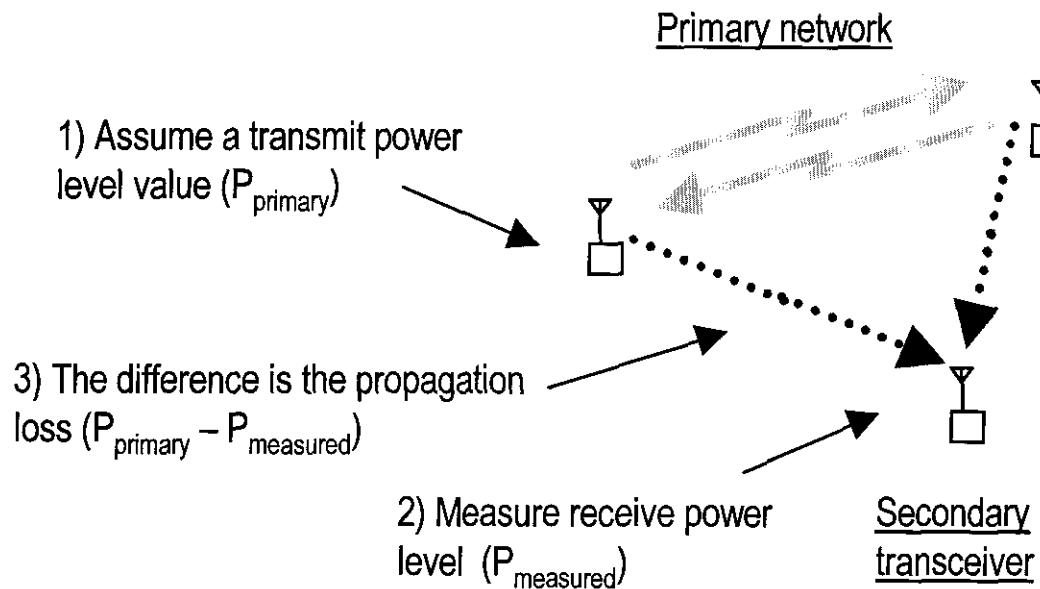
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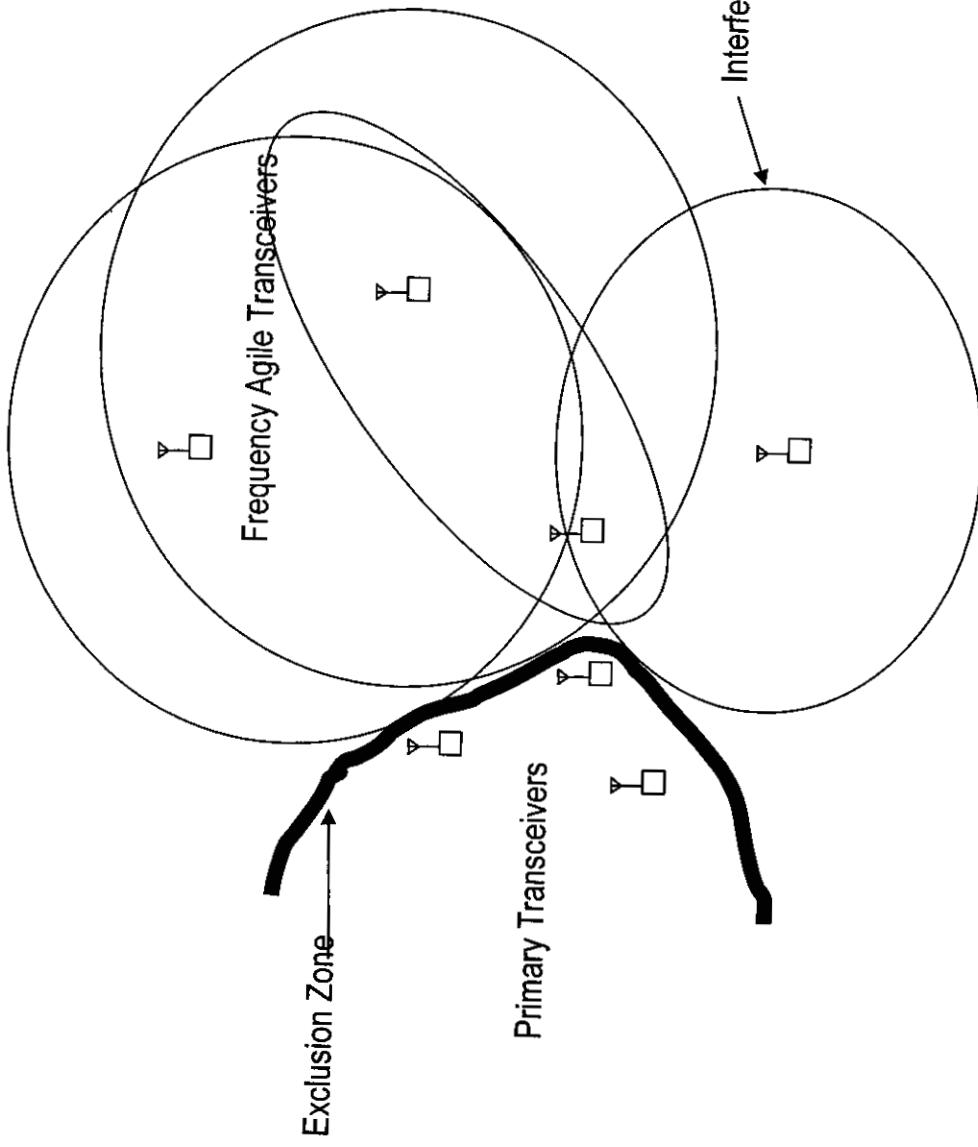
Adaptive, Receive-Only Spectrum Access Method

$$P_{\max \text{ TX}} = P_{\text{allowable interference}} + P_{\text{primary}} - P_{\text{measured}}$$



- $P_{\max \text{ TX}} = 10 * \log_{10}(k * T * B) + P_{\text{Primary}} - P_{\text{measured}} - \text{Margin}$
 - Margin = 10 to 20 dB, required for cumulative effects, rapid propagation changes, false alarm minimization
 - T – Interference Noise Temperature, in K
 - B = signal bandwidth, in Hz

Frequency Agile Coverage “Morphs” To Fit Primary Users

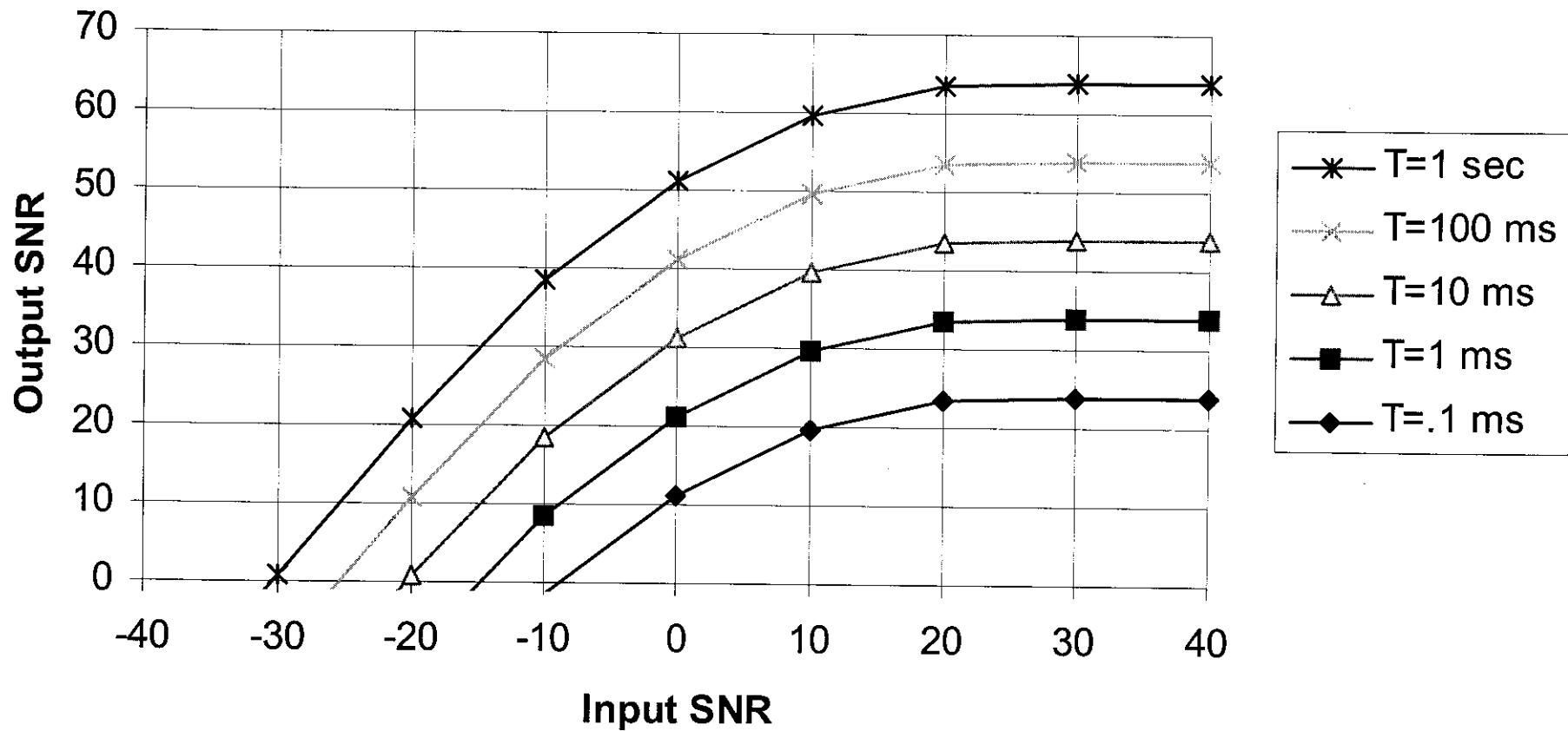


Hidden-node problem overcome by each Frequency Agile transceiver listening to all Primary users within range



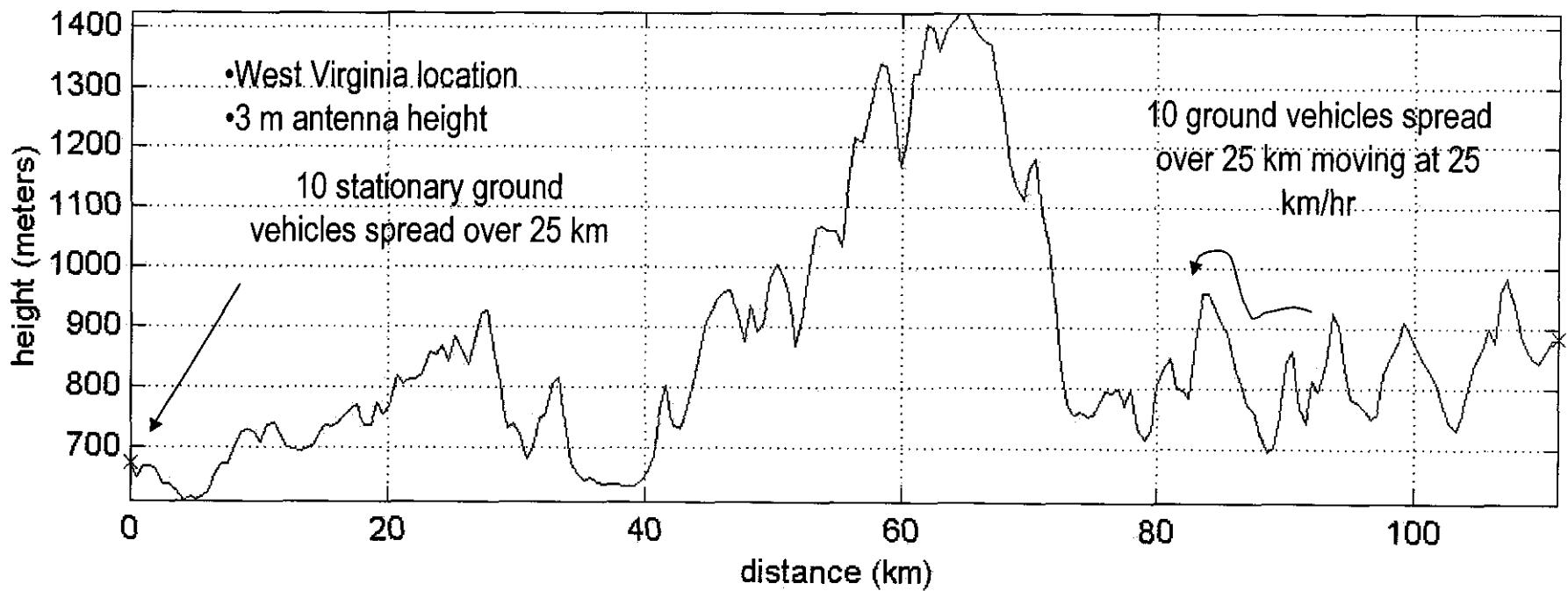
High Sensitivity Receiver Performance

Cyclic Correlation Output SNR



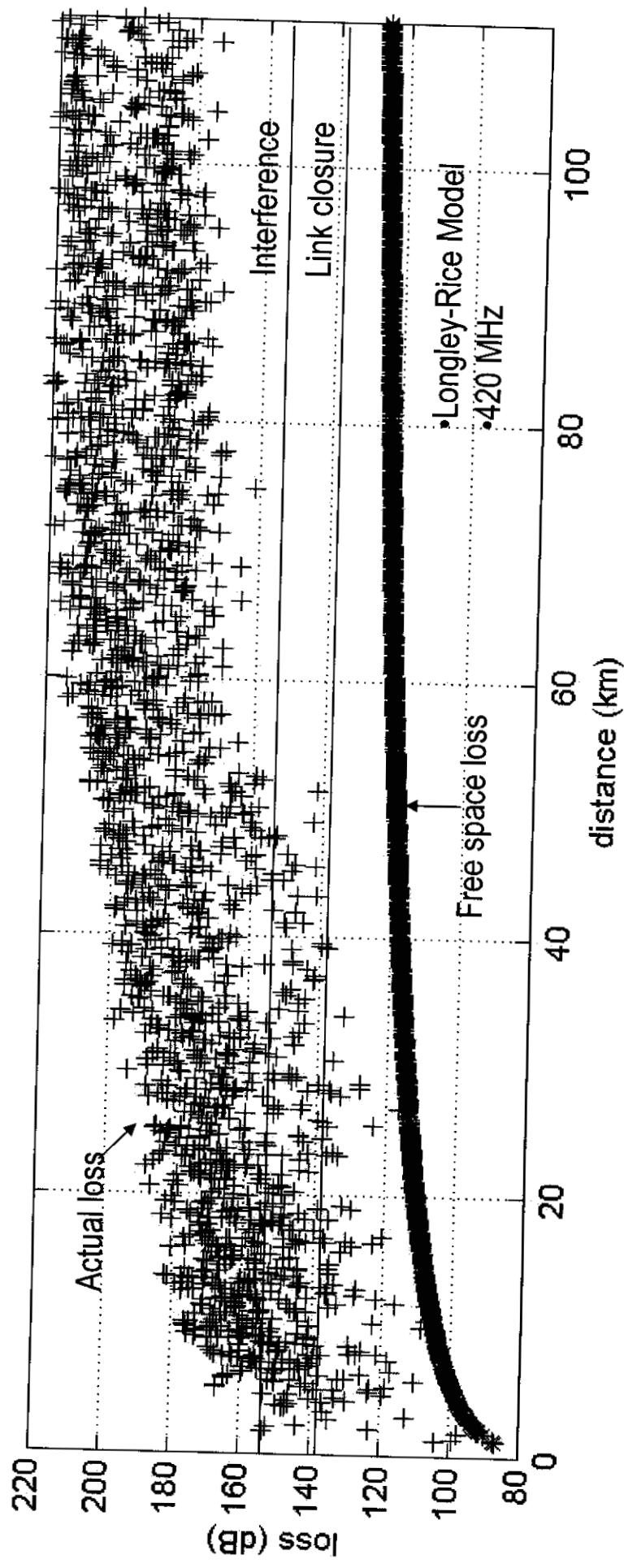


Simulation Example



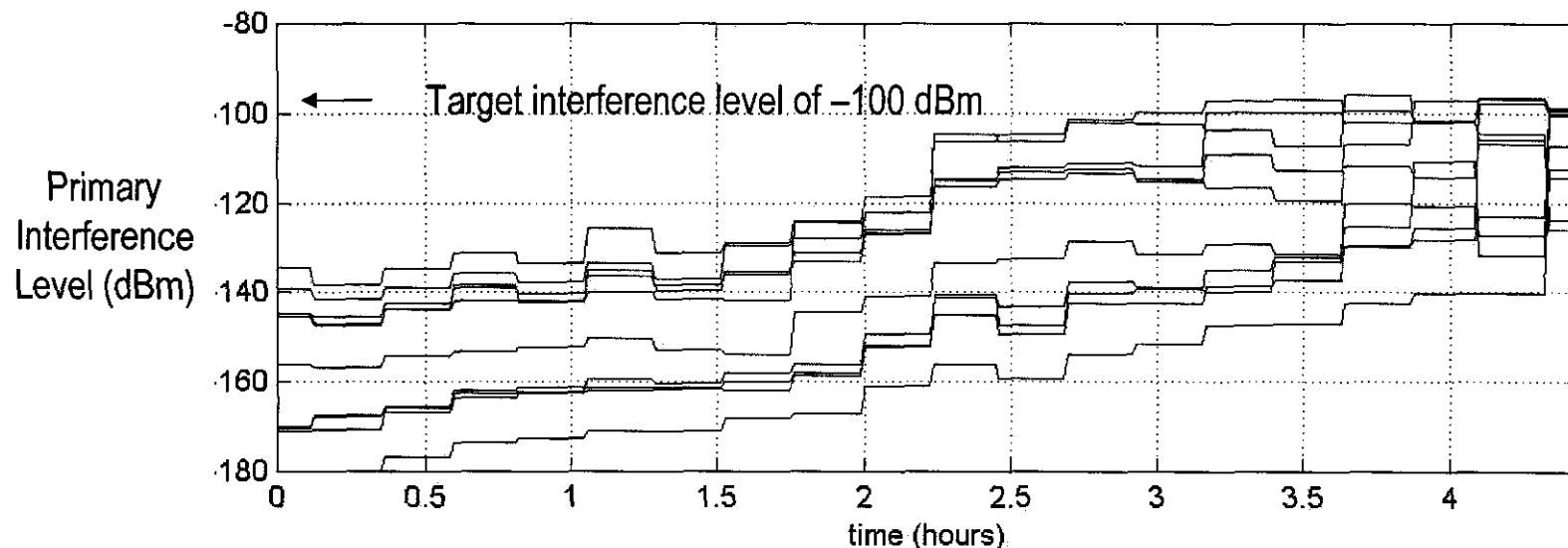
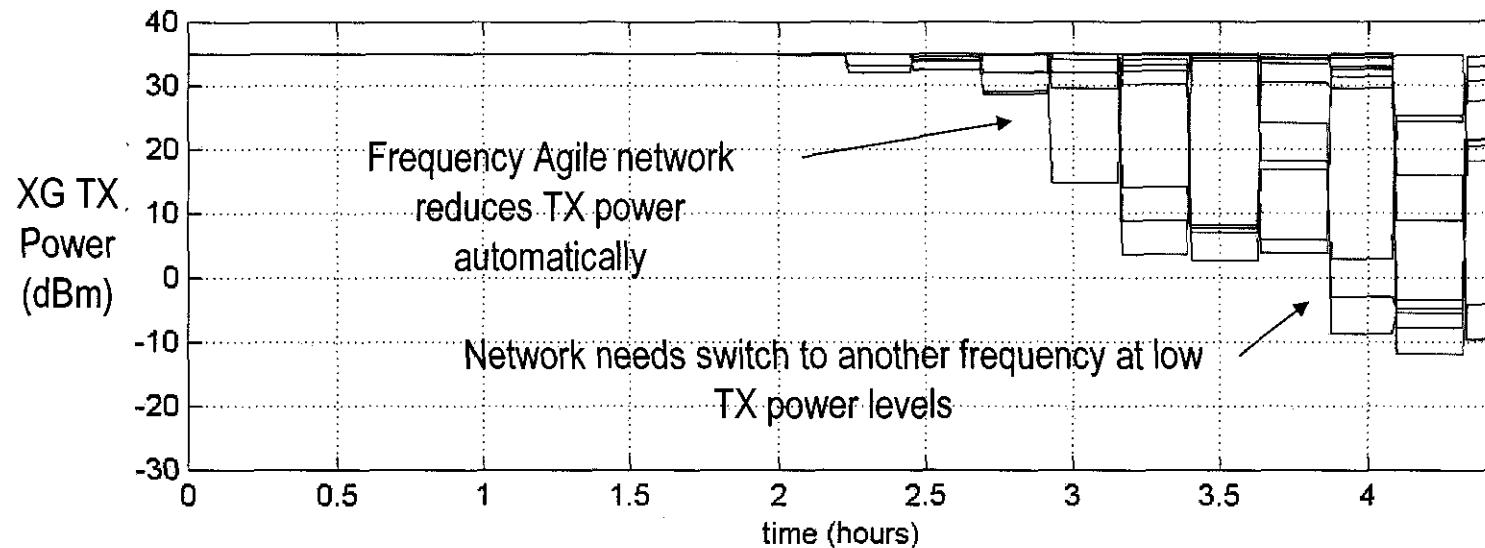
- Primary users are stationary
- XG users are mobile
- Omni-directional antennas
- 420 MHz signal frequency

Propagation LOSSES



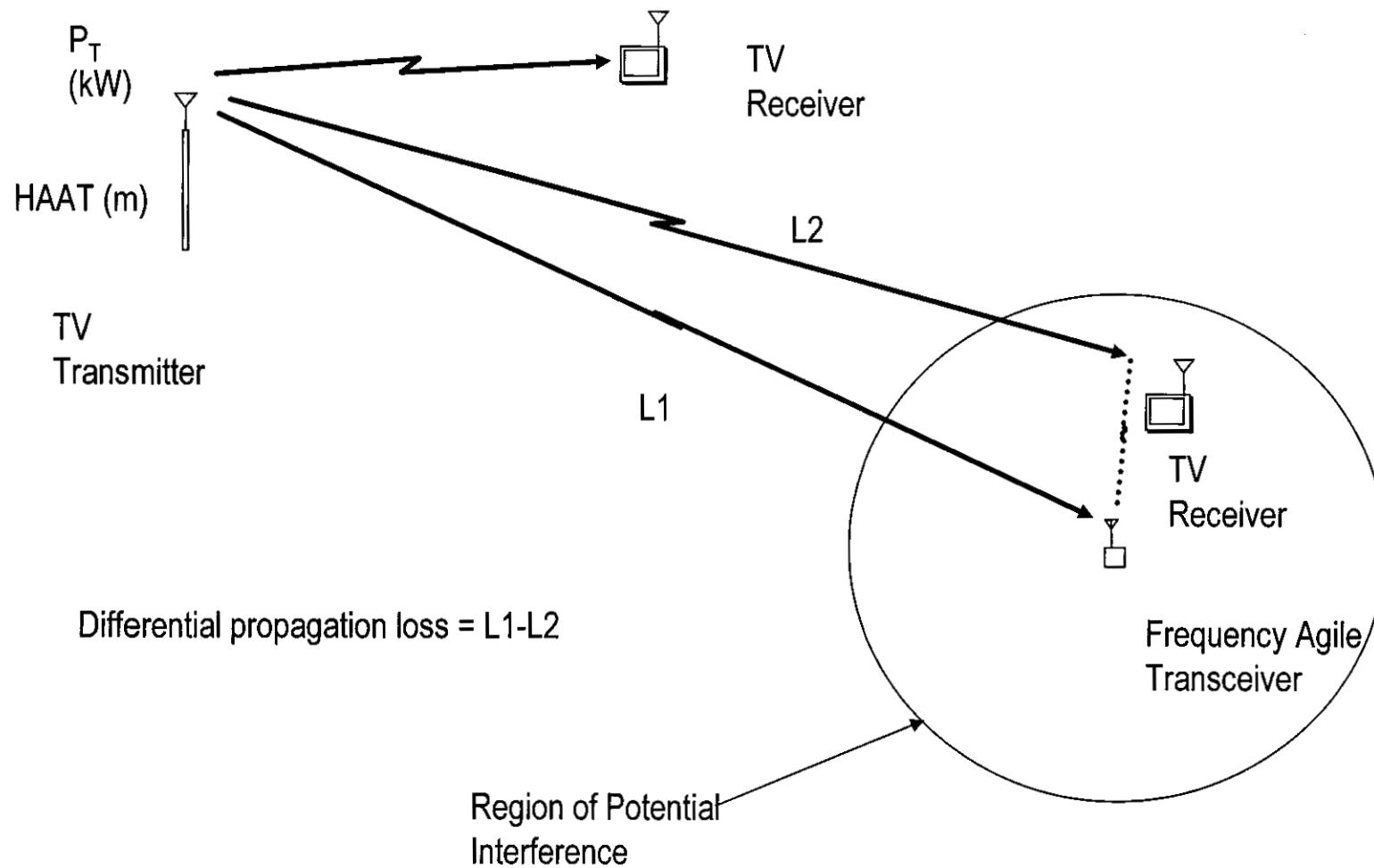


TX Power and Interference





Listen-Only Method in the Broadcast Bands



Transmit Power Rule

$P_{max\ TX} = P_0$ if Primary signal is not detected

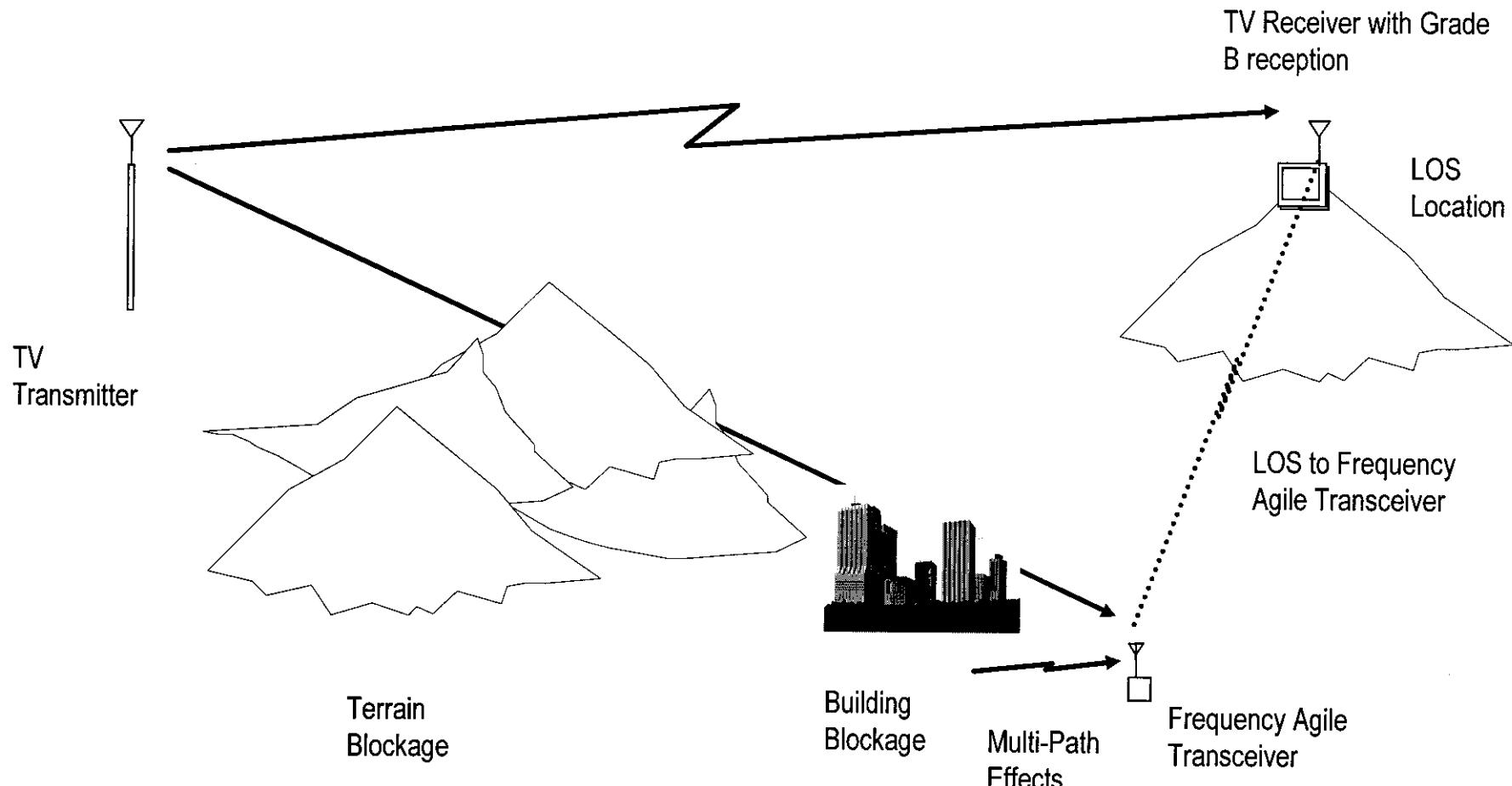
= Transmission prohibited if Primary signal is detected

where, $P_{max\ TX}$ = Frequency Agile transmitter power level, in dBm

P_0 = specified power value, in dBm



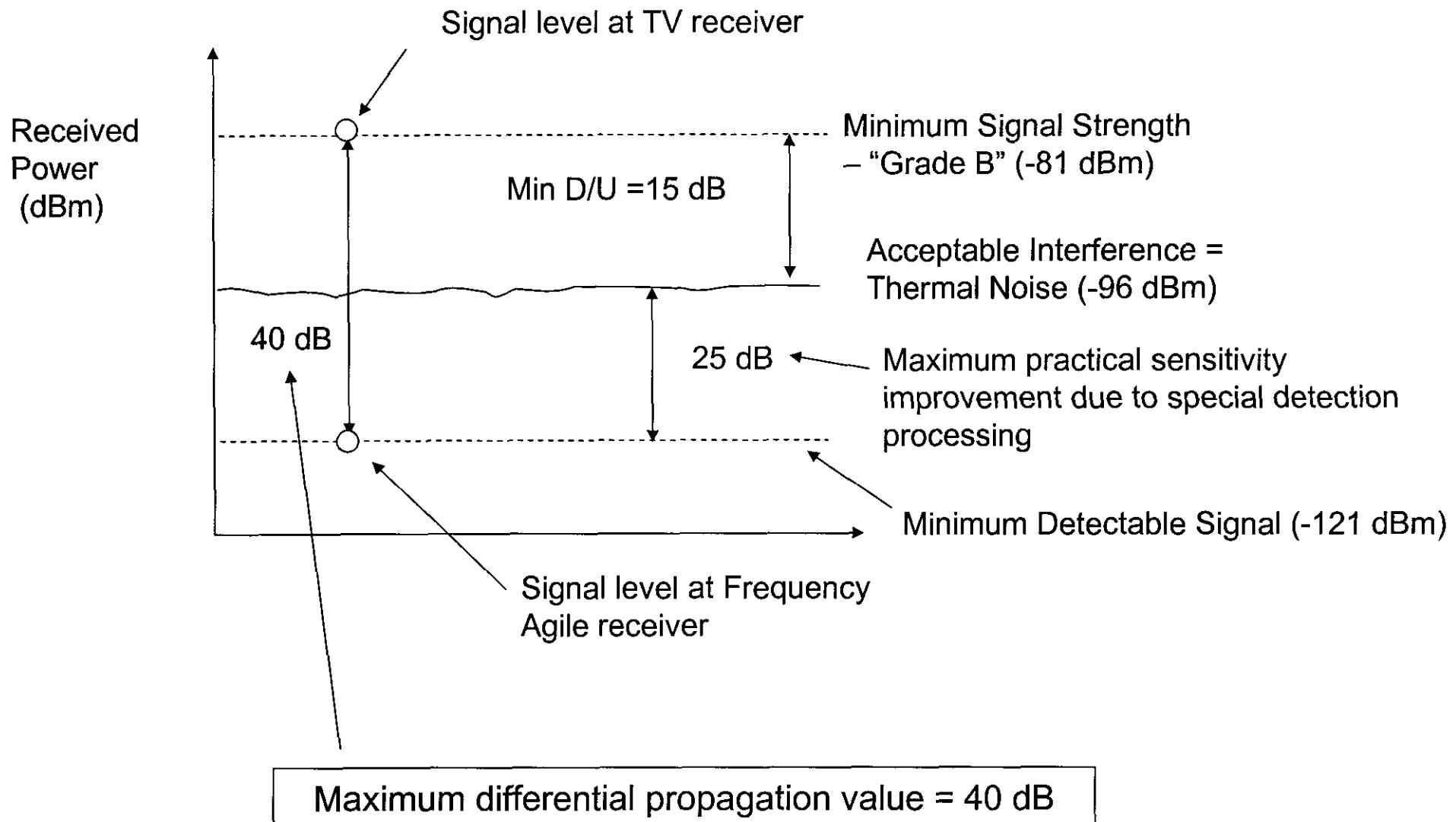
Minimal Interference



- Joint probability of three conditions
 - Agile Receiver doesn't detect TV signal
 - Primary user receives TV signal
 - $D/U < 15 \text{ dB}$



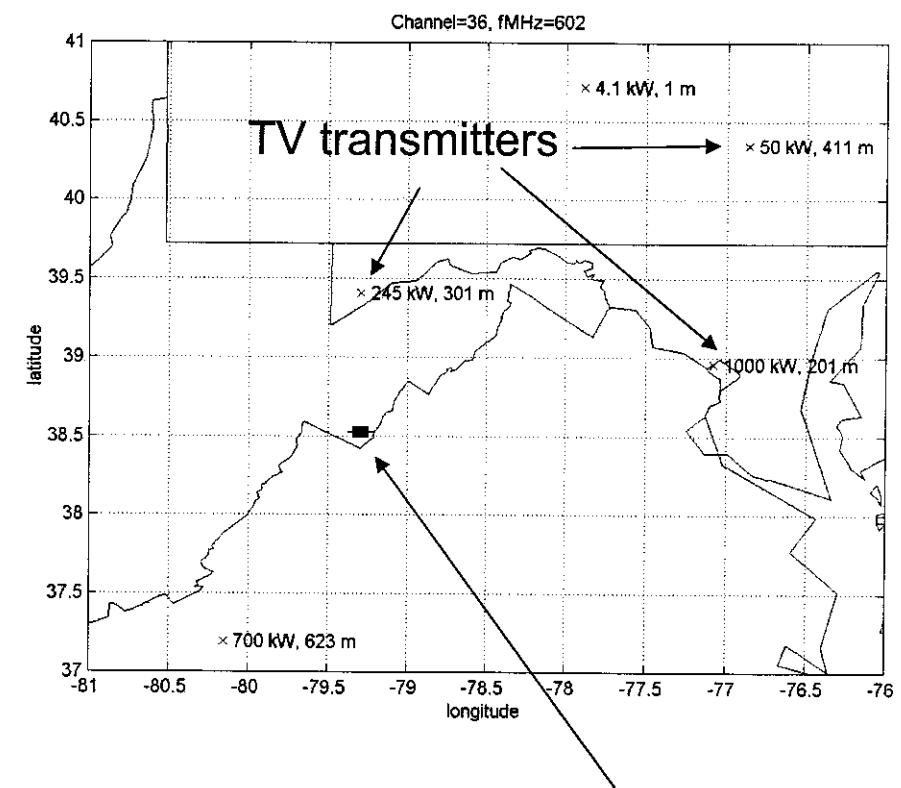
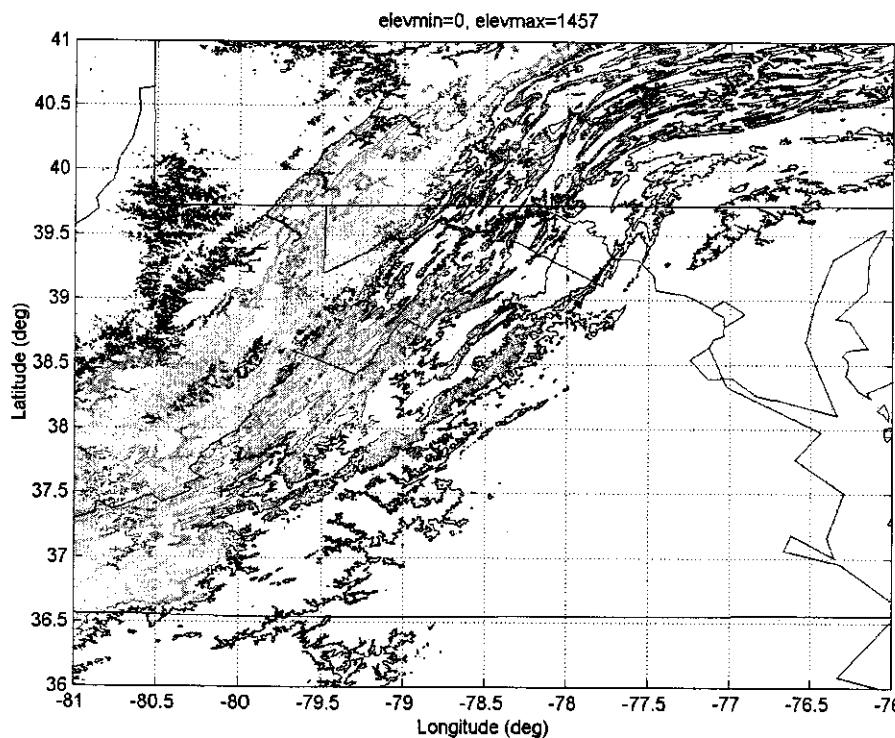
Maximum Differential Propagation Value





Simulation of Differential Propagation

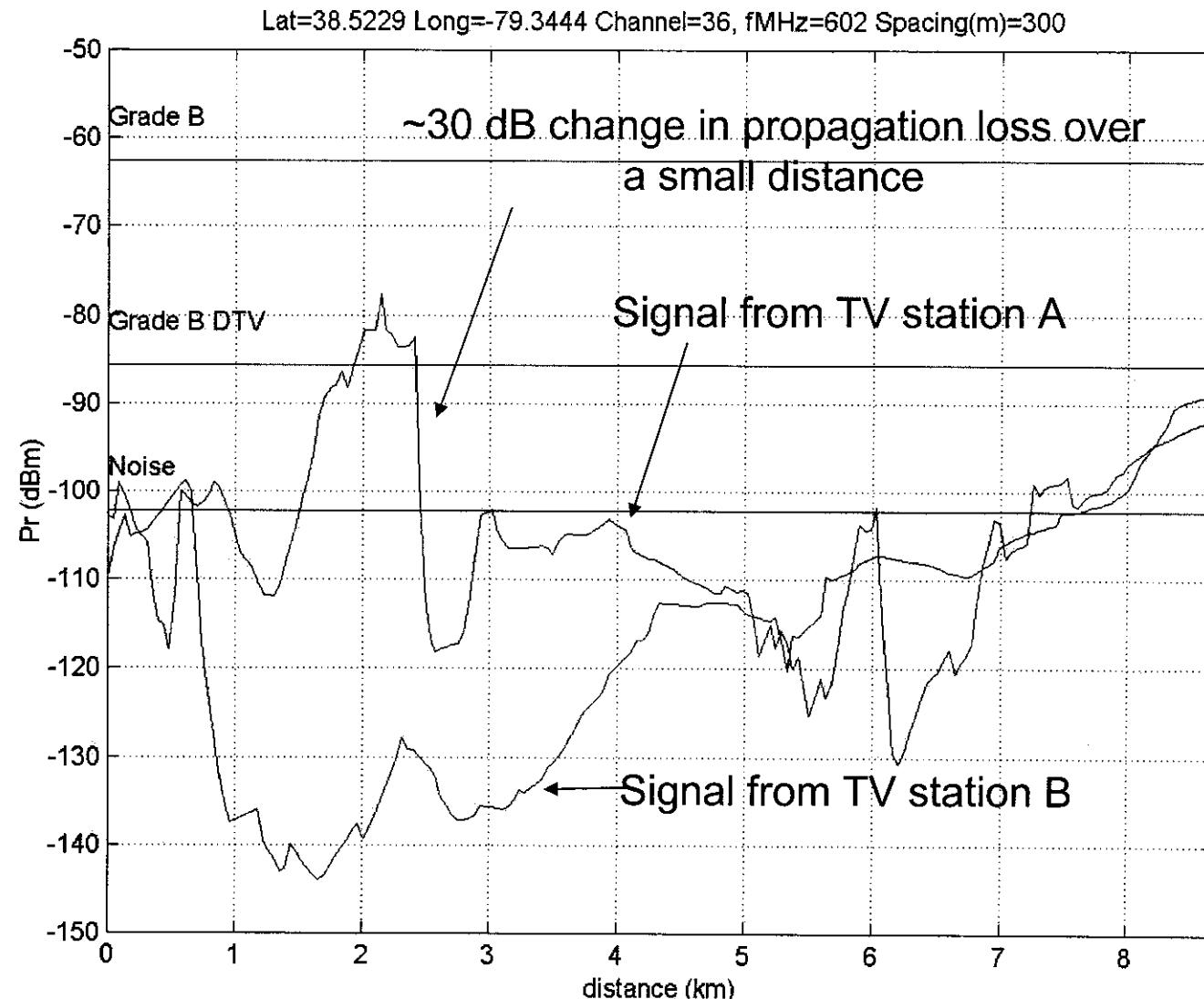
Scenario – Mid-Atlantic Region
Elevation contours

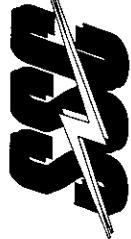


Test reception points along a ~ 8 km path



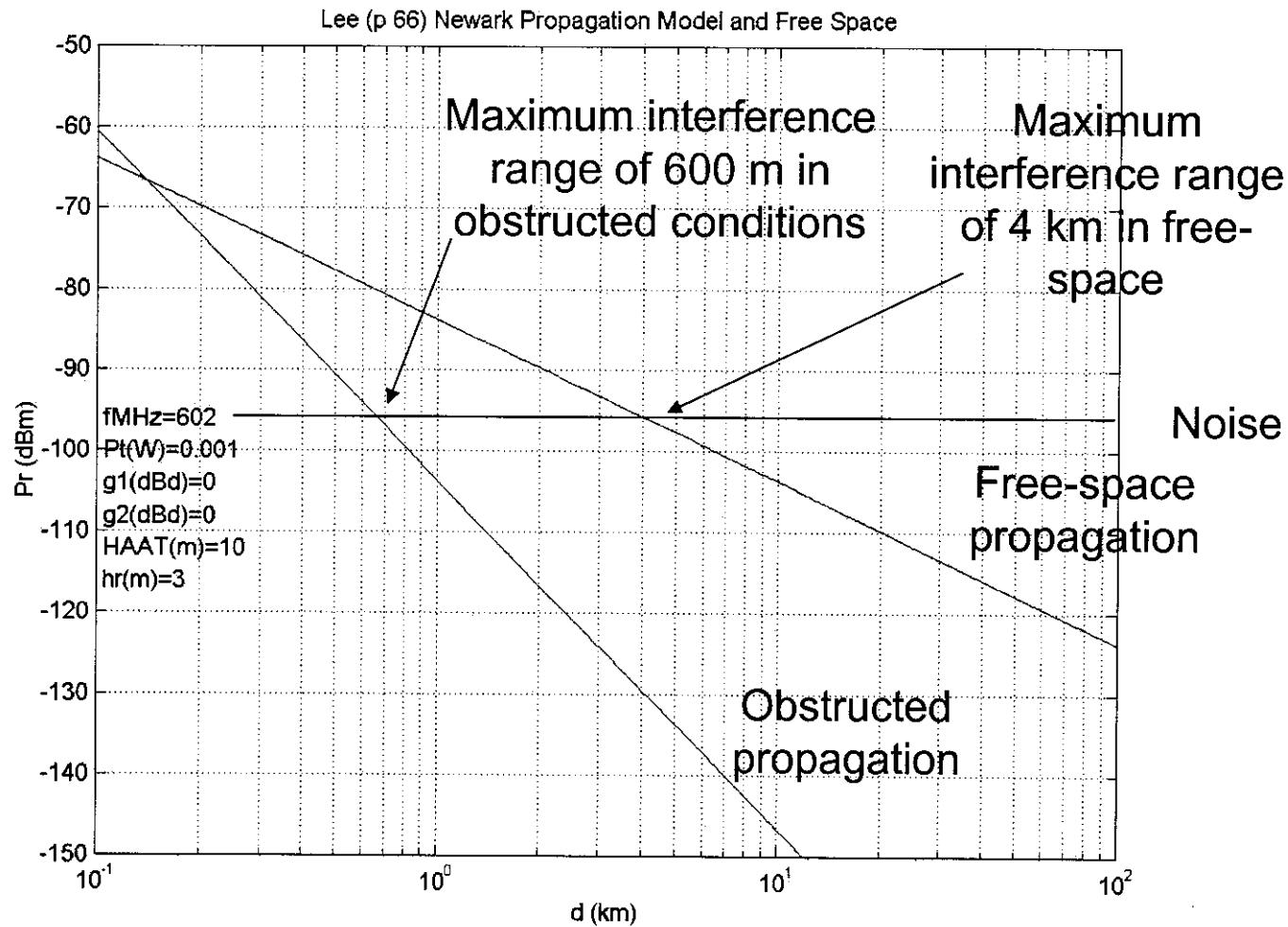
Large Change in Propagation Loss over a Short Distance is Rare





Low Power Transmitters Have a Small Interference Range

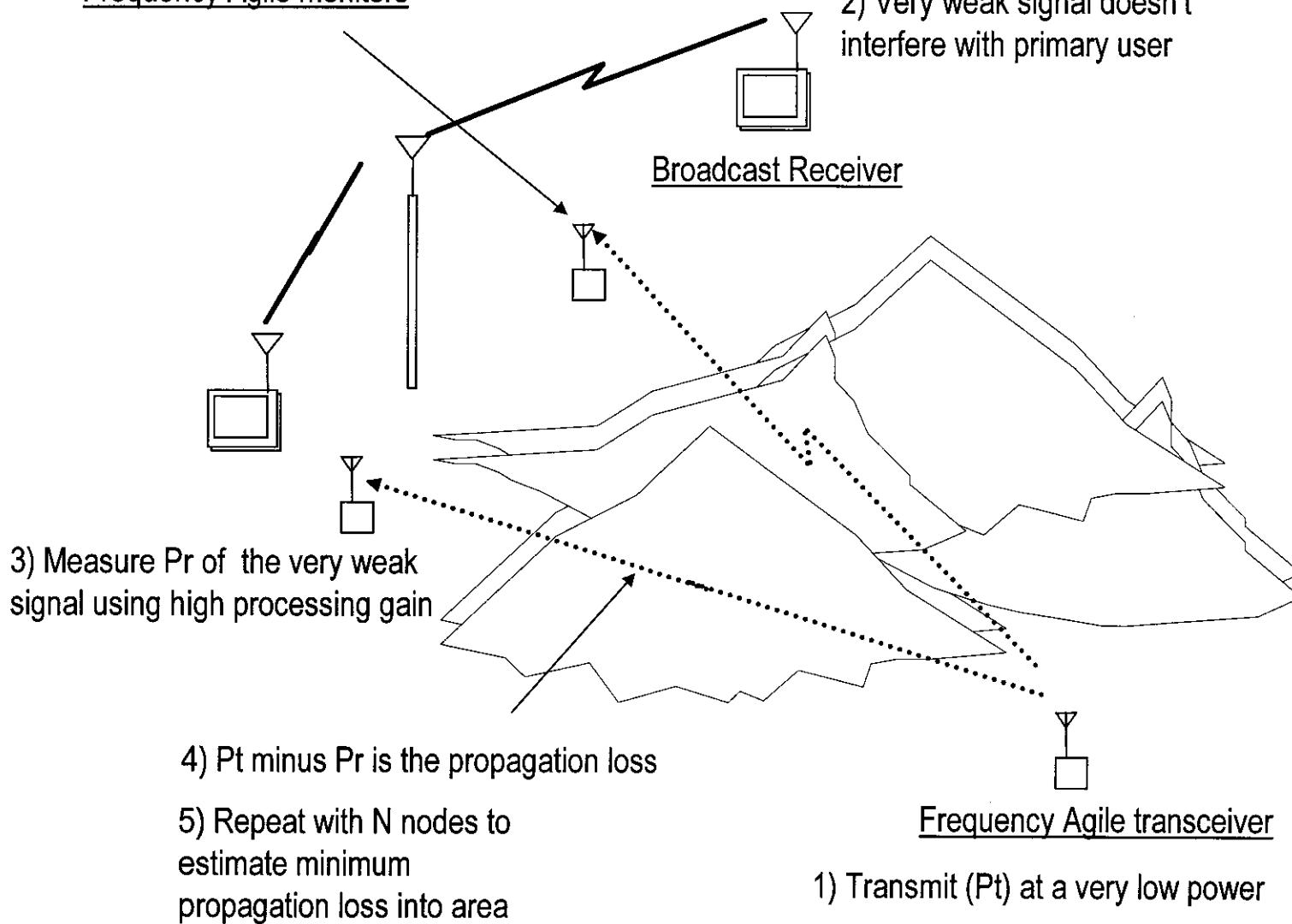
1 mW transmit power





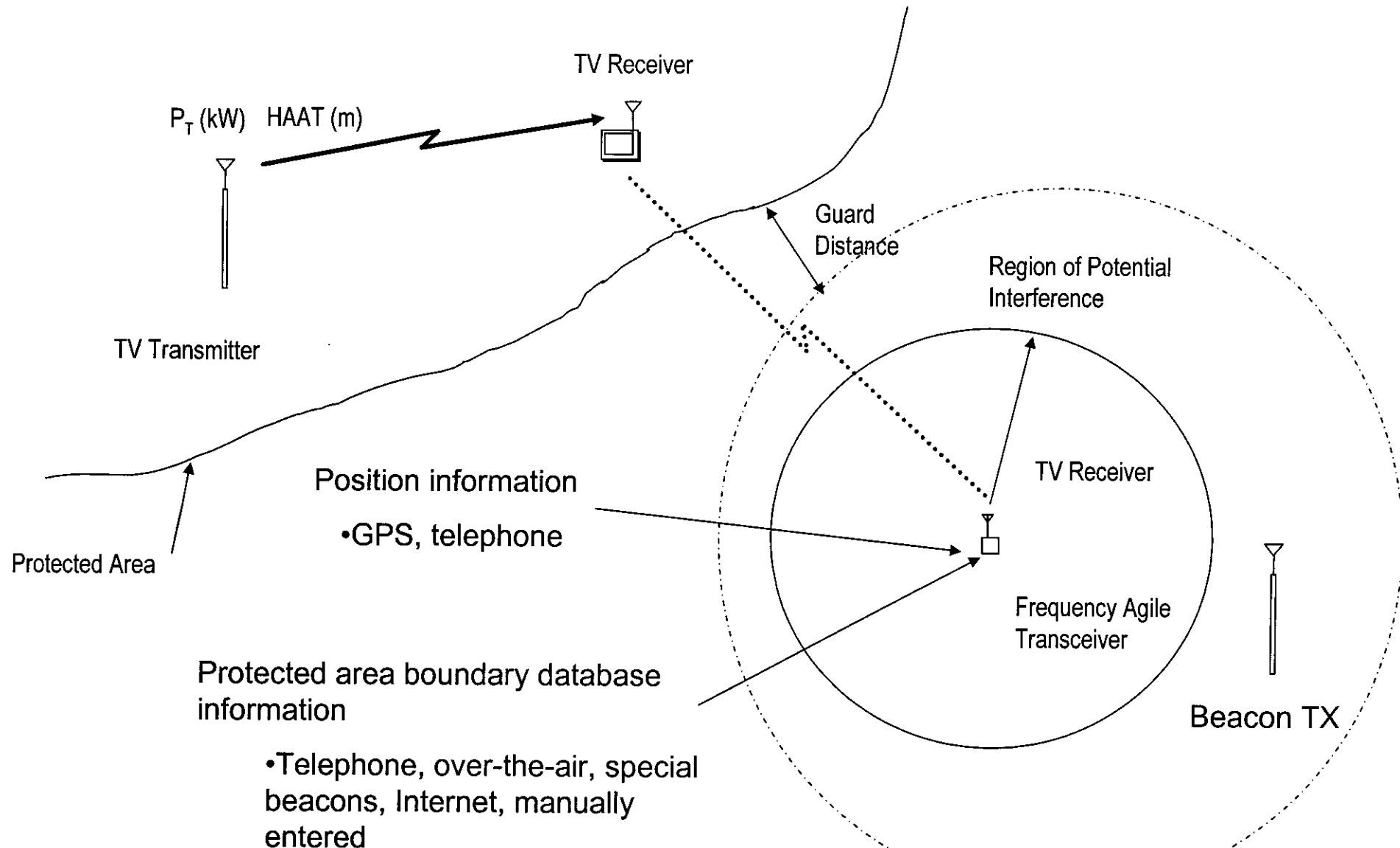
Spectrum Probing Method

Frequency Agile monitors



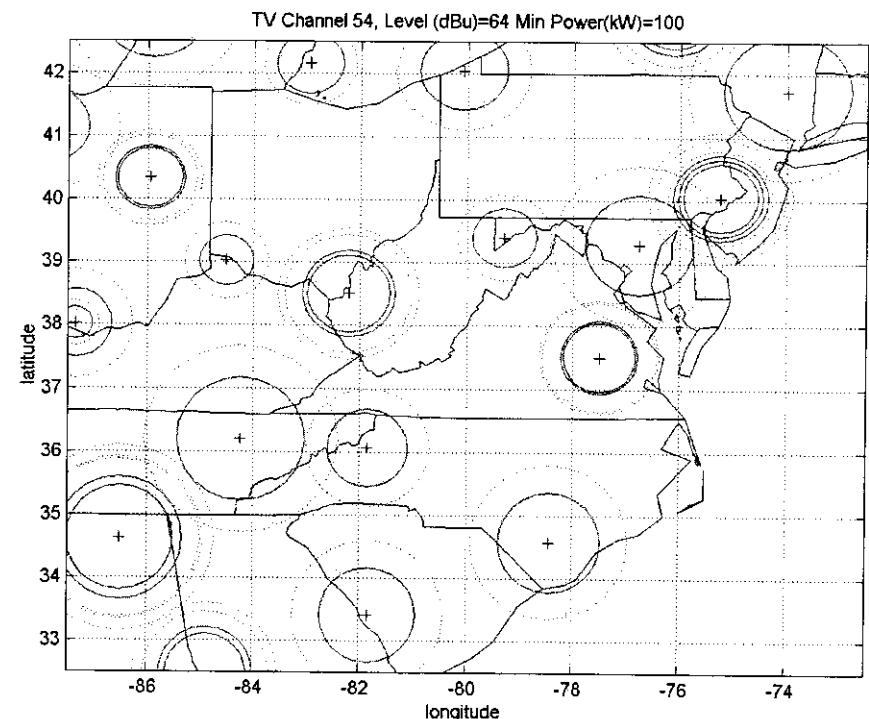
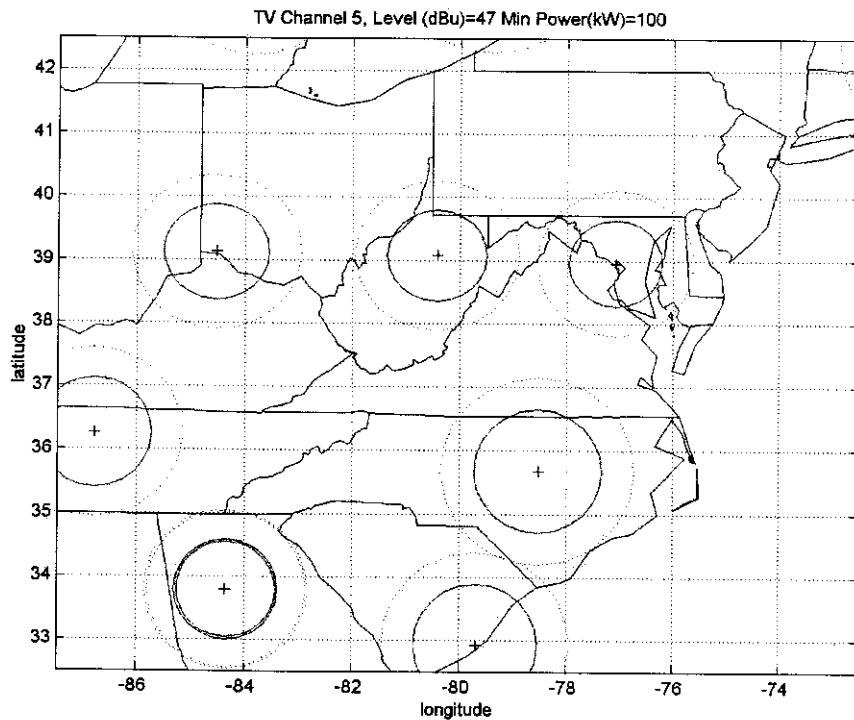


Geo-Location Method





Significant “White Space” Between TV Coverage Areas

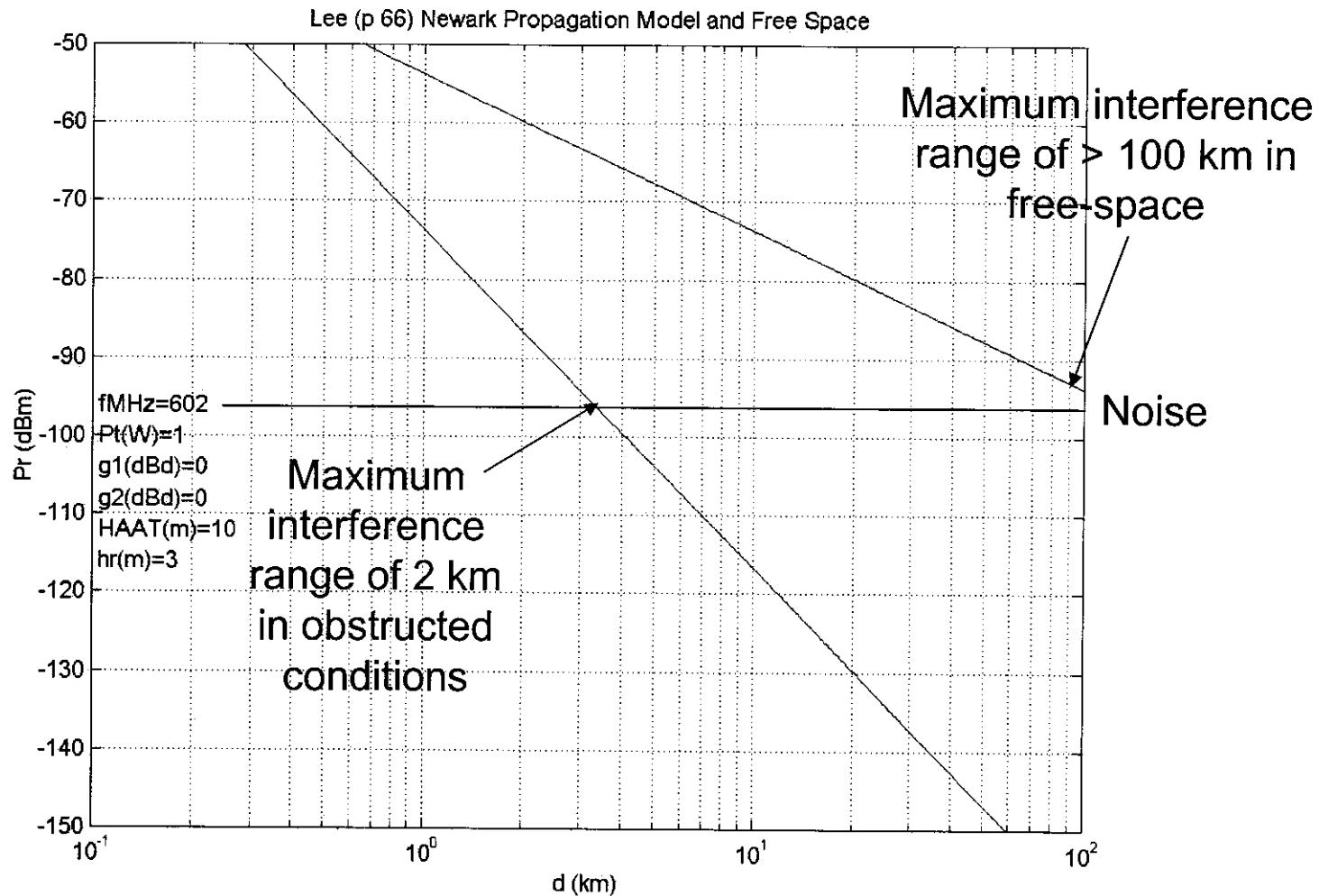


Grade B 50% and 90% contours
Channel 5 and channel 54



How Large A Guard Distance?

1 W transmit power



Large guard distances reduce spectrum harvest
TV bands: 100 km is too large >> Limit TX power to mW's
Other bands: Max TX power ?



Summary

- Multiple, robust spectrum access methods
 - Listen-Before Talk
 - “TDMA” spectrum
 - Broadcast spectrum
 - Geo-location/database
- FCC should conduct and publish spectrum occupancy measurements
 - Many spectrum holes are large and have long duration
- FCC should allow experimental interactive operations
 - All access methods including Probe
 - TV and other bands